CLAIMS

What is claimed is:

1. In a method of digital image enhancement of a multidimensional digital image, said image being represented by a matrix [d] comprising image parameters, wherein said matrix [d] is mathematically manipulated to solve a linear ill-posed problem to reduce blurring, the improvement comprising: imposing a constraint on a reconstructed image matrix, said constraint being based upon minimization of the area where strong variations and discontinuities between said image parameters occur.

2. In the method of claim 1, the improvement further comprising: implementing said constraint in the form of weights imposed upon said image parameters.

3. In the method of claim 2, the improvement further comprising: imposing penalization upon said image parameters, thereby to keep said said paramters within reasonable limits of variation.

4. In the method of claim 3, the improvement further comprising: solving said ill-posed problem by means of an iterative loop using a programmed computer.

5. In the method of claim 4, stopping said iterative loop when the norm of a difference between the observed degraded image and a numerically predicted degraded image corresponding to an iteratively sharpened image reaches a tolerance value.

6. A method of digital image enhancement of a multidimensional digital image, said image being represented by a matrix [d] comprising image parameters, comprising the steps of:

a) initially restoring a digital image [m] by applying a transposed complex conjugated blurring operator, and an inverse gradient operator to the initial degraded digital image [d];

b) computing an inverse sharpening filter, thereby to minimize the area where strong image parameter variations and discontinuities occur;

c) constructing a partially sharpened weighted image by applying said inverse sharpening filter;

d) constructing an inverse filtered image by inverse filtering said partially sharpened weighted image using said inverse sharpening filter and said inverse gradient operator;

e) checking the norm of a difference between the observed degraded image and a numerically predicted degraded image corresponding to said sharpened image; if said norm is equal to or less than a user defined tolerance value, then calculating the nonblurred image; otherwise, continuing to step f);

f) undoing the results of loop steps comprising steps b), c), d), and e); and returning to step b).

7. The method of claim 6 further including, subsequent to step d, and prior to step e), the additional step of imposing penalization to said inverse filtered image, thereby forcing the image parameters to be distributed within an interval bounded by a first upper value and a first lower value.

8. The method of claim 6 wherein said digital image is represented by a 2- dimensional matrix [d].

9. The method of claim 6 wherein said digital image is represented by a 3- dimensional matrix [d].

10. The method of claim 6 wherein one or more calculations comprised by steps of said method are performed using a programmed computer.

11. The method of claim 6 wherein said inverse sharpening filter of step b is constructed using constraints comprising weights imposed upon image parameters.

12. The method of claim 11 wherein said inverse sharpening filter comprises a minimum gradient support constraint.

13. The method of claim 6 wherein step c further includes using conjugate gradient re-weighted optimization.

14. The method according to claim 6, wherein: said step b)further comprises the steps of determining the spatial gradient of the partially sharpened image parameters and subsequently deriving a variable weighting function accomplishing a minimum gradient support constraint based upon minimizing the area of a nonzero spatial gradient of the image parameters.

15. The method according to claim 14, wherein: said minimum gradient support constraint is of the form $\frac{\|\nabla m\|^2}{\|\nabla m\|^2+e^2}$ = minimum.

16. The method according to claim 6, wherein: said step c) futher includes the step of solving the following numerical formula for $(n+1)$-th iterations:

$$\widehat{m}^w_{g,n+1} = \widehat{m}^w_{g,n} + \delta\widehat{m}^w_{g,n} = \widehat{m}^w_{g,n} - k_n\tilde{l}(\widehat{m}^w_{g,n}),$$

wherein weighted conjugate gradient directions $\tilde{l}(\widehat{m}^w_{g,n})$ are determined by the expressions:

$$\tilde{l}(\widehat{m}^w_{g,n}) = \hat{l}(\widehat{m}^w_{g,n}) + \beta_n\tilde{l}(\widehat{m}^w_{g,n-1}),$$

$$\hat{l}(\hat{m}^w_{g,n}) = \widehat{W}^{-1}_{en}\widehat{B}^*_g\left(\widehat{B}_g\left(\widehat{W}^{-1}_{en}\widehat{m}^w_{g,n}\right) - \hat{d}\right) + \alpha\hat{m}^w_{g,n},$$

and $\widehat{W}_{en}$ is the matrix of said sharpening filter, wherein the length of the step k_n is determined by the line search to the minimum of the functional of the weighted image parameters $P^\alpha_g\left(\widehat{m}^w_{g,n} - k_n\tilde{l}(\widehat{m}^w_{g,n})\right)$. , and parameter β_n is calculated by the formula:

$$\beta_n = \frac{\left\|\hat{l}(\widehat{m}^w_{g,n})\right\|^2}{\left\|\hat{l}(\widehat{m}^w_{g,n-1})\right\|^2}.$$

17. The method according to claim 6, wherein: said step d) further comprises recomputing the real parameters of the ideal image from the weighted parameters $\widehat{m}^w_{g,n+1}$ at the $(n+1)$-th iteration by solving the following numerical formula:

$$\widehat{m}_{n+1} = \widehat{\nabla}^{-1}\widehat{W}^{-1}_{e(n+1)}\widehat{m}^w_{g,n+1}.$$

18. The method according to claim 7, wherein: said step imposing penalization comprises imposing the upper bound $m_a^{ub}(\mathbf{r})$ for the positive anomalous image parameter values, and the lower bound $-m_a^{lb}(\mathbf{r})$ for the negative anomalous image parameter values, and discarding all the values outside these bounds during the entire image restoration process, thereby to keep the image parameters values $m_n(\mathbf{r})$ always distributed within the interval:

$$m_{bg}(\mathbf{r}) - m_a^{lb}(\mathbf{r}) \preceq m_n(\mathbf{r}) \preceq m_{bg}(\mathbf{r}) + m_a^{ub}(\mathbf{r}).$$